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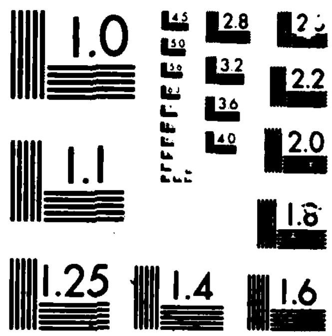
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Sleep loss appears to influence subsequent exercise in a manner dependent upon the nature of that exercise. To investigate this, we examined the effect of 24 sleepless hours on the ability to produce and maintain maximal ventilation, a form of exercise involving a limited muscle mass. We found that sleep loss reduced maximal ventilatory output and also resulted in persistent mood changes. In addition, sleep loss worsened performance of both short-and long-term maximal ventilation, indicating that its influence was not limited to prolonged, boring tasks. We concluded that those forms of exercise utilizing the largest muscle mass are most resistant to the influence of sleep deprivation.

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SLEEP DEPRIVATION AND EXERCISE TOLERANCE

Annual Report

Bruce J. Martin, Ph.D.

February 1, 1985 - January 31, 1986

Supported by

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SUMMARY

A 24-hour sleepless period

a) reduces short-term maximal ventilation
b) reduces prolonged isocapnic maximal ventilation
c) reduces short-term isocapnic submaximal ventilation
d) increases sleepiness and worsens mood

We conclude that sleep loss has effects on small muscle mass performance at least as great as those evidenced in work requiring a larger muscle mass.

FOREWORD

For the protection of human subjects this investigator has adhered to policies of applicable Federal Law 45 CFR 46.

Statement of the Problem

Sleep deprivation is a common occurrence in both the military and civilian spheres. In many cases, severe or prolonged exercise follows sleep loss. In many instances, this exercise involves a small, not large muscle mass. Because we know nothing of how variation in active muscle mass influences sleep deprivation's effects, this study was undertaken.

Background

Previous work under this contract identified several effects of sleep deprivation upon subsequent exercise. Sleep loss did not influence VO_2max or short-term work tolerance (1), while it did blunt the ability to carry out long-term heavy exercise (2, 3), in proportion to the "dosage" of sleeplessness. Measurements of physiological responses to exercise after sleep loss revealed no clear effects on oxygen uptake, heart rate, minute ventilation or blood lactate. In addition, prolonged mild exercise provoked no greater or lesser stress hormonal (B-endorphin, cortisol) response after sleep loss than it did after normal sleep (4). Most provocatively, this form of exercise significantly reduced mood disturbance and sleepiness when carried out for 3 hours.

Approach to the Problem

These previous results provoked our inquiry into the relation of muscle mass involved in exercise to the sleep loss effect. By investigating small-muscle mass exercise, we could examine the components of "arousal" that make mild treadmill walking such an effective antidote to sleepiness after sleep loss. By using respiratory muscles as our small muscle group, we could at the same time approach the question of sleep loss influence on one of the components of respiratory failure.

Results and Discussion

Twelve young healthy persons volunteered to serve as subjects. All were studied twice in counterbalanced fashion, once after normal sleep and once after a single sleepless night (24 sleepless hours). Both short and long-term maximal ventilation was measured, with all tests maintained isocapnic. Mood and sleepiness was assessed before and during the ventilatory maneuvers. 12-s, 1-min, and 30-min maximal isocapnic voluntary ventilations were measured, as was a 1-min test at 75% of maximal effort.

The results of the study are listed below:

1) Sleep loss increased sleepiness (raw score)

Control	Sleep-deprived	p
1.92	4.25	<0.01
$\pm$.26	$\pm$.39	

and sleepiness during the 30-min MVV increased above that before the maneuver began.

Before	During	p
4.25	5.00	<0.01
±.39	.43	

While sleepiness was unchanged in the control situation:

Before	During	p
1.92	2.08	NS
±.26	±.31	

Discussion: Prolonged dynamic exercise involving a small muscle mass is ineffective as a means of arousal, even when performed maximally. The failure of this exercise to blunt sleepiness, when treadmill walking did suggest the presence of a muscle-mass dependent effect.

2) Sleep loss worsened mood:

Total mood disturbance (raw score)

	Control	Sleep-deprived	p
Before tests	5.7 ± 8.0	41.6 ± 8.8	<0.07
During 30-min MVV	5.7 ± 6.8	47.8 ± 10.9	<0.07

Discussion: Thus, there was no worsening during the MVV. The mood disturbance, as is typical after sleep loss, was composed largely of increased fatigue and confusion, and decreased vigor. Tension, anxiety, and depression were unaltered.

3) Sleep loss reduced maximal voluntary ventilation ($l.min^{-1}$ BTPS):

	Control	Sleep-deprived	p
72-sec MVV	168.8 ± 12.2	156.8 ± 11.5	<0.05
1-min MVV	129.4 ± 7.4	116.9 ± 7.0	<0.01
30-min MVV	100.6 ± 6.2	86.7 ± 6.4	<0.01

Discussion: The change averaged 7-12% and was equally large at short-term as at long-term exercise. This contrasts with previous work suggesting that the ability to perform short-term, high-intensity work is preserved after sleep loss. Interestingly, at every minute of the 30-min MVV, maximal ventilation was significantly lower after sleep deprivation. Also, submaximal ventilation was reduced by sleep loss:

	Control	Sleep loss	p
1 min at 3/4 maximal effort	92 ± 6.4	84.9 ± 6.0	<0.05

This result suggests that sleep deprivation has skewed the entire perceptive range of voluntary ventilatory effort.

Conclusions

Small muscle mass exercise is hindered at least as much or more than is work utilizing larger muscle masses when sleep deprivation precedes exercise. This effort, though undetermined is speculated to arise from the reduced stimulus for arousal inherent in small muscle mass work.

Recommendations

Although sleep loss is relatively ineffective as a direct inhibitor of exercise, this may be exercise intensity and mode dependent. Exercise involving smaller amounts of muscle, even when maximal, may allow psychological sleep loss effects to powerfully undermine performance.

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